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Rotary Friction Welding Process and Rotary Friction Welding Machine

The invention relates to a rotary friction welding process in accordance with the preamble of Patent Claim 1. In addition, the invention relates to a rotary friction welding machine in accordance with the preamble of Patent Claim 8.

Friction welding is a widespread joining method for the fabrication of gas turbines. Friction welding is considered a part of the so-called pressure welding process, whereby in terms of friction welding a differentiation is made between so-called linear friction welding and rotary friction welding and so-called friction stir welding. The present invention relates to so-called rotary friction welding in which rotationally symmetrical components are joined to one another or connected to one another via friction. In rotary friction welding a first component rotates, while the other component is stationary and is pressed with a specific force against the rotating component. In this case, the joining surfaces of the components being connected to one another adapt to one another via hot forging.

When connecting two rotationally symmetrical components with the aid of rotary friction welding it is important that the two components that are being connected to one another be aligned precisely with one another after the rotary friction welding. A part of doing this, on the one hand, is that the longitudinal center axes of the two components being connected to one another are stacked or coincide, and that, on the other hand, in the circumferential direction of the rotationally symmetrical components, a pre-specified relative position or angularity is maintained between the two components being connected to one another. Maintaining the pre-specified angularity between the two components being connected to one another in the circumferential direction of the rotationally symmetrical components is called clocking. If the rotationally symmetrical components being connected to one another are integrally bladed rotor disks or so-called blisks (bladed disks), the relative position in the circumferential direction is pre-specified by the desired relative blade position of the two integrally bladed rotors. Maintaining the pre-specified relative position or the angularity in the circumferential direction is of crucial importance especially when connecting integrally bladed rotor disks for manufacturing so-called blisk drums.

US 5,858,142 discloses a rotary friction welding process in which maintaining the pre-specified relative position or angularity in the circumferential direction of the components being connected to one another, i.e., so-called clocking, is realized by targeted braking of the rotating component. The disadvantage of the rotary friction welding process according to US 5,858,142 is that, among other things, during the

braking of the rotating component, high moments are in effect, which can lead to a distortion of the entire rotary friction welding machine and thus to a reduced precision of the connection produced with the aid of rotary friction welding. In addition, the time required to brake the rotating component is relatively long so that there is relatively high uncertainty with respect to the pre-specified relative position that has to be maintained in the circumferential direction between the rotationally symmetrically components being connected to one another.

Starting from this, the object of the present invention is to create a novel rotary friction welding process and a corresponding rotary friction welding machine.

This object is achieved in that the aforementioned rotary friction welding process is developed further by the features of the characterizing portion of Patent Claim 1. According to the invention, a relative position in the circumferential direction and a compression between the components being connected to one another are measured, whereby then, when a pre-specified compression and a pre-specified relative position are reached, the stationary component is released in such a way that it rotates jointly with the rotating component.

Therefore, it is proposed, in accordance with the present invention, that when a pre-specified compression and a relative position in the circumferential direction between the components being connected to one another are reached, the stationary component is released so that it can rotate jointly with the rotating component. It directly follows therefrom that no moments must be absorbed in order to brake. The advantageous result of this is that the rotary friction welding machine no longer distorts. The precision of the connection produced with the aid of rotary friction welding can be increased as a result. In addition, according to the present invention, it is possible during rotary friction welding to precisely adjust the compression that is being adjusted between the components being connected to one another. The quality of the rotary friction welding also increases as a result. It is possible with the present invention to connect finished, integrally bladed rotor disks to one another into so-called blisk drums by using rotary friction welding.

According to an advantageous development of the invention, when both components are connected to one another and rotating jointly, an additional compression occurs. To do so, the two components that are connected to one another and rotating jointly are pressed against one another with a specific force.

Preferred developments of the invention are yielded from the dependent claims and the following description. Without being limited hereto, exemplary embodiments of the invention are explained in greater detail on the basis of the drawings. They show in:

Fig. 1 a schematic depiction of a rotary friction welding machine;

Fig. 2 a connecting seam between two components that are connected to one another;

Fig. 3 a schematic detail from a rotary friction welding machine in accordance with the invention; and

Fig. 4 the same detail as Fig. 3 in another operating state.

Fig. 1 shows the principle structure of a rotary friction welding machine 10 for joining two components 11 and 12, wherein the connecting seam 13 depicted in an enlarged manner in Fig. 2 is embodied between the components 11 and 12 during rotary friction welding. The rotary friction welding machine 10 in accordance with the prior art that is depicted in Fig. 1 has a first spindle 14 and a second spindle 15. Arranged or positioned on the first spindle 14 is the component 11 and on the second spindle 15 is the component 12 of the components 11 and 12 being connecting to one another. For this purpose, tensioning devices 16 and 17 are allocated to each of the spindles 14 and 15. The components 11 and 12 being connected to one another can be fastened to the respective spindle 14 or 15 using the tensioning devices 16 and 17. At least one flywheel mass body 23 is allocated to the first spindle.

In order to connect the two components 11 and 12 to one another using rotary friction welding, the component 11 positioned on the first spindle 14 is rotated in the direction of arrow 18, wherein the component 12 positioned on the second spindle 15 is pressed against the component 11 in the direction of arrow 19 with a force. The relative rotation between the components 11 and 12 and this force generate friction and therefore heat the two components 11 and 12 on the contact surfaces or joining surfaces 21, 22 of said components. In this case, a hot forging of the material of components 11 and 12 takes place on the contact surfaces or the joining surfaces 21, 22, and the connection bead 20 depicted schematically in Fig. 2 forms in the process.

When connecting the two components 11 and 12, it is important that the longitudinal axes or the longitudinal center axes of the two components 11 and 12 be stacked or coincide after connection and that there is consequently no offset between the longitudinal axes. In addition, the two components 11 and 12 must be connected to one another in such a way that there is a pre-specified relative position or angularity (so-called clocking) between the two components 11 and 12 in the circumferential direction of the rotationally symmetrical components 11 and 12.

According to the present invention, in a first step of the rotary friction welding process, the component 11 positioned on the first spindle 14 is moved rotationally and the non-rotating component 12 positioned on the second spindle 15 is pressed with a pre-specified force against the rotating component 11. In the process, the joining surfaces 21 and 22 of the components 11 and 12 being connected to one another adapt to one another, compression is realized between the components 11 and 12 being connected to one another, and a connection bead 20 is formed.

The present invention provides for online monitoring of the compression, on the one hand, and the relative position, on the other hand, in the circumferential direction between the components 11 and 12 being connected to one another during rotary friction welding. If, in doing so, it is established that a pre-specified compression and a pre-specified relative position has been reached in the circumferential direction between the components 11 and 12 being connected to one another, then, in a second step of the rotary friction welding process according to the invention, the stationary component 12, which is arranged on the second spindle 15, is released such that it can rotate jointly with the rotating component 11. This can be realized in that the second spindle 15 is released and can rotate jointly with the component 11 or the first spindle 14.

Moreover, according to the present invention, when both components 11 and 12 that are connected to one another are rotating jointly, a re-compression is performed with an increased compressive force. To do this, the components 11 and 12 that are connected to one another and rotating jointly are pressed against one another with a specific force.

It must be noted at this point that directly after releasing the stationary component 12 when a pre-specified compression as well as a relative position has been reached between the components 11 and 12 being connected to one another, the component 11 already rotates with the full rotational speed of the first spindle 14, but the previously stationary component 12 must be accelerated to the rotational speed of the already rotating component 11. Inertial forces act during this acceleration of the previously stationary component 12 to the rotational speed of the rotating component 11. Because of these inertial forces, the relative position or angularity in the circumferential direction between the components 11 and 12 being

connected to one another is subject to change during the acceleration of the previously stationary component 12. This change is taken into account according the present invention for determining the point in time at which the previously stationary component 12 is released. The relative position between the two components 11 and 12, at which the previously stationary component 12 is released is determined as a function of the masses of the two components 11 and 12 being connected to one another and as a function of the rotational speed of the rotating component 11. The masses of the components 11 and 12 being connected to one another and the rotational speed of the rotating component 11 can be used to draw conclusions about the change in the relative position or angularity between the components 11 and 12 being connected to one another during the acceleration of the previously stationary component 12. The relative position between the components 11 and 12 upon termination of the rotary friction welding is yielded from a vectorial addition of the relative position between the components being connecting to one another upon release of the stationary component 12 and the change in the relative position during the acceleration phase of the stationary component 12.

The rotary friction welding process according to the invention is subdivided, accordingly, into two steps as already explained above. In a first step, the component 11 is moved rotationally and the component 12 is stationary and is pressed with a pre-specified force against the rotating component 11. The compression that forms in the process as well the relative position in the circumferential direction of the components 11 and 12 being connected to one another are measured and monitored. If it is established in the process that a pre-specified compression and a pre-specified relative position between the components being connected to one another have been reached, then the second step of the rotary friction welding process according to the invention is initiated in that the stationary component 12 is released so that it can rotate jointly with the rotating component 11. To do so, the previously stationary component 12 must first be accelerated to the rotational speed of the rotating component 11. Following this, a re-compression of the components 11 and 12 that are connected to one another and rotating jointly is performed. The relative position or angularity in the circumferential direction of the components being connected to one another is no longer subject to change. The pre-specified relative position or angularity in the

circumferential direction, at which the release of the previously stationary component 12 takes place, is yielded from the desired relative position or angularity between the two components 11 and 12 being connected to one another corrected by the amount by which the relative position or angularity changes during the acceleration of the previously stationary component 12 to the rotational speed of the rotating component 11.

According to the present invention, a novel rotary friction welding machine is also proposed in addition to the rotary friction welding process. The essential details of the rotary friction welding machine according to the invention for conducting the rotary friction welding process according to the invention are that the second spindle 15, on which the stationary component 12 is positioned, is blocked by a holding device. During this first step of the rotary friction welding process according to the invention, the holding device blocks the second spindle 15 and keeps said spindle fixed accordingly. In the second step of the rotary friction welding process according to the invention, however, the holding device releases the second spindle 15 so that said spindle can rotate.

The holding device for blocking as well as loosening the second spindle 15 can be embodied as depicted in Figs. 3 and 4 for example. In the exemplary embodiment in Figs. 3 and 4, permanent magnets 24 and 25 are allocated to the second spindle 15. The holding device is formed by electromagnets 26, which are embodied to have a polarity that can be reversed. In the depiction in Fig. 3, the electromagnets 26 are polarized so that the second spindle 15 is blocked. In the depiction in Fig. 4, however, the polarity of the electromagnets 26 has been reversed so that the second spindle 15 can rotate in the direction of the arrow 27. After the polarity is reversed, the magnetic holding device serves as a magnet bearing.

In order to monitor the compression between the components 11 and 12 being connected to one another as well as to monitor the relative position in the circumferential direction of the components 11 and 12 being connected to one another, corresponding measuring devices are allocated to the rotary friction welding machine according to the invention. The two spindles 14 and 15 are preferably positioned on low-friction axial bearings, particularly on roller bearings, so that in the second phase of the rotary friction welding process according to the invention, in which both components 11 and 12 being connected to one another rotate at the same rotational speed, a compressive force for re-compressing can be applied to the two components 11 and 12.

The rotary friction welding process according to the invention, as well as the rotary friction welding machine according to the invention, can be used to connect finished, integrally bladed rotor disks with the correct angle orientation to blisk drums. The compression between the integrally bladed rotor disks being connected to one another can be set very precisely. The danger of distorting the rotary friction welding machine and therefore negatively impacting the connection between the integrally bladed rotor disks being connected to one another by the moment, which would have had to be absorbed if the previously stationary component were not released, is eliminated. Overall, the rotary friction welding process according to the invention consequently distinguishes itself due to a very precise connection between the components being connected.